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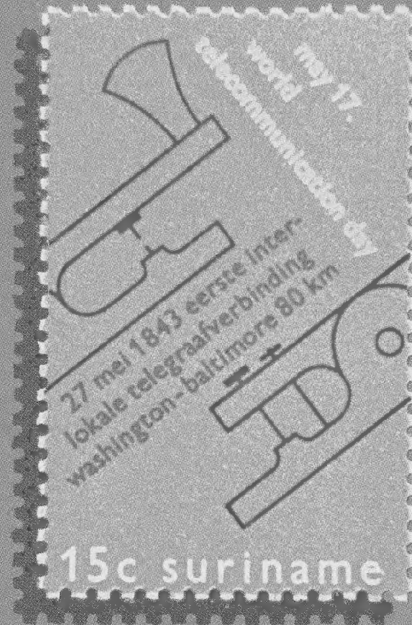

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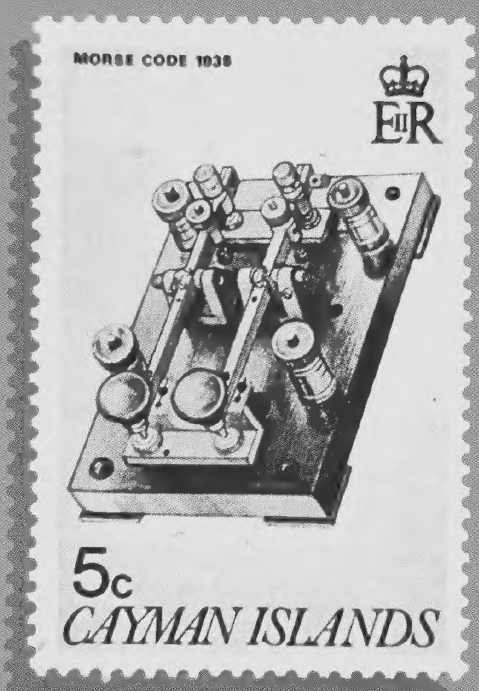
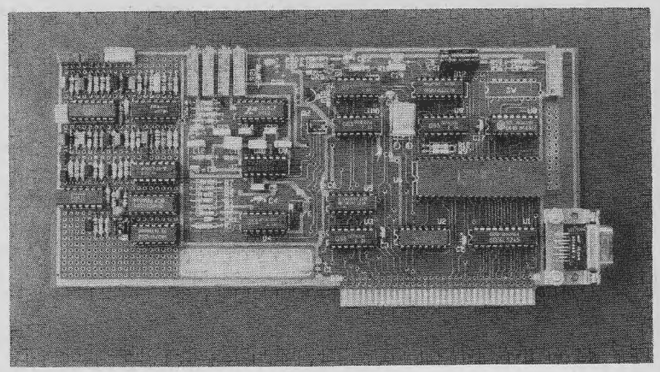


focus on communications technology

Fast, reliable modem cuts connect time



a 4800 baud modem for VHF/UHF packet radio

Do you sometimes feel guilty of hogging your local packet network when you have a large file or message to transfer? Here's a modem that can cut down on your connect time.

A wide variety of radios now work with this modem. Reliability is high enough that our local digipeater (VE3PKT) has been switched exclusively to 4800 baud and has been running trouble free for many months. We will show how you can add a 4800 baud modem to the HAPN-1 packet radio adapter. It fits nicely into the card's "prototype area" for experimenters.*

A software switch provided with the HAPN-1 adapter lets you change from the standard (built-in) 1200 baud modem to this one. The interface between the packet card and radio is arranged to accommodate both modems; all it takes to switch from one speed to the other is a keyboard selection.

Although the bandwidth used in VHF and UHF voice operation could support data rates higher than 4800 baud, HAPN chose 4800 baud for the following reasons:

- Most existing VHF or UHF radios can be used.
- No major changes to your radio or TNC (terminal node controller) should be required.
- Alignment and setup should be easy.
- It uses no exotic or difficult to obtain parts.
- It uses the same bandwidth as normal 2-meter voice operation.
- 4800 baud provides nearly four times the effective data rate of 1200 baud.

The modem contains an on-board squelch circuit that activates in approximately 10 milliseconds, typically 10 to 30 times faster than the squelch in most radios. As a result, clear-to-send delays (Tx-delay) and turnaround times are shorter, reducing "wasted channel" time.

principles of operation

Most packet radio TNCs include a modem; other telecommunication groups treat the modem as a separate entity. Its purpose is to transform the serial, digital data into a form compatible with the transmitting medium — in our case, a VHF 2-meter radio. It also must take a noisy, undulating voltage from the radio receiver and change it into a digital data stream acceptable to the TNC. Our current packet radio system requires the TNC to know when the radio channel is in use; this is the modem's job too.

transmitting duobinary codes

The digital data coming into the modem is a stream of ones and zeroes that modulate the transmitter's rf

*The HAPN-1 adapter is a terminal node controller on a board that plugs into a slot on an IBM PC or compatible microcomputer.[1] HAPN is also designing a version to work with the TAPR TNC-2 compatible unit. It will reside on a "daughter board" that plugs into J4, a connector provided by TAPR for an external modem, and work off a single +12 volt supply. The board will contain a multiplexer making it possible to switch between 1200 and 4800 baud easily. This board is currently in the prototyping stage.

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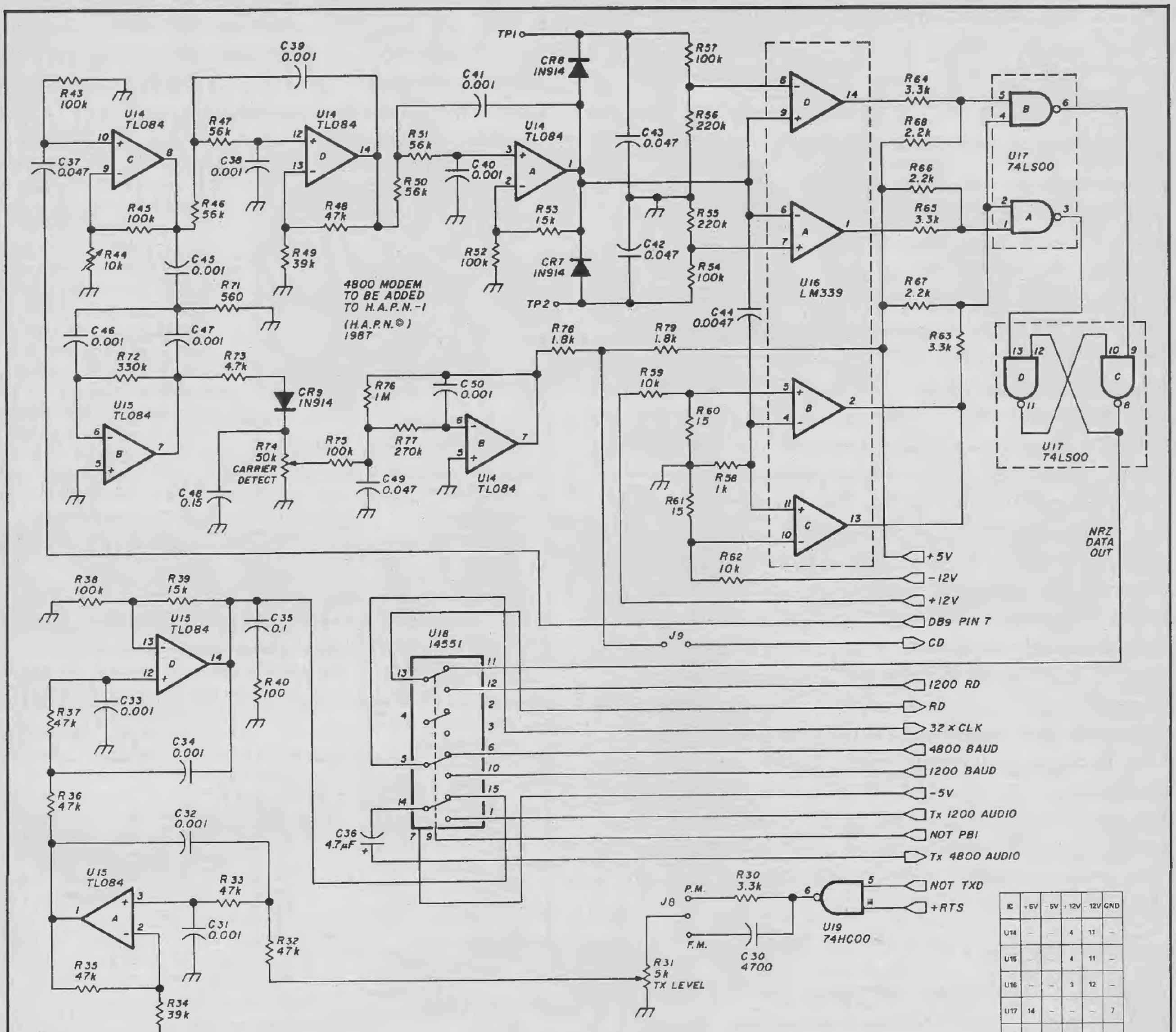

IC	+5V	-5V	+12V	-12V	GND
U14	–	–	4	11	–
U15	–	–	4	11	–
U16	–	–	3	12	–
U17	14	–	–	–	7
U18	16	7	–	–	8
U19	14	–	–	–	7

fig. 1. 4800 baud modem.

carrier. This modem uses a duobinary coding system where a 0 to 1 transition momentarily shifts the carrier *up* in frequency, then back to center. The carrier is shifted *down* in frequency and then back to center by a 1 to 0 transition. If two or more consecutive ones come along, the carrier shift occurs only for the first 1, returning back to center for the rest. Similarly, a string of two or more zeroes shifts the carrier down in frequency only for the first 0, returning to center for the rest. Because the frequency of the carrier is changed in frequency only for the first 0, returning does not require a data randomizer to avoid data-sensitivity errors caused by the carrier drifting from the center of the channel.

All these transitions are smoothed out by a four-pole low-pass filter before they reach the radio's modulator. The filter prevents spurious sidebands from interfering with adjacent channels (see **fig. 1**). The shape of the waveform going into the rig's modulator must be carefully controlled. Most rigs amplify the microphone signal with rather nonlinear amplifiers that can severely distort these waveshapes. You can get the best results when the signal is tapped into the frequency modulator directly, bypassing the rig's audio stages.

What happens with a rig using a phase modulator? A phase modulator can be accommodated by modifying the shape of the waveform input. A jumper, J8, in the modem chooses one of two waveshapes to be filtered for either frequency (FM) or phase (PM) type

modulators. This modulation scheme works well with frequency synthesized radios. Tap points in both receiver and transmitter that work for this modem also seem to work for 1200 baud modems.

receiving duobinary codes

After getting into the receiver, the frequency-modulated signals pass into the radio's FM detector. Every detector type (ratio detector, quadrature, etc.) yields the same shape waveform. It will be the same shape whether it is generated from a PM or FM modulator (**fig. 2**). The voltage waveform output is proportional to the frequency excursions of the transmitting signal — positive pulses returning to zero and negative pulses returning to zero. The receiving part of the modem must discriminate between positive-going pulses, no pulses, and negative-going pulses.

After amplification by U14c, the signals are filtered by a four-pole low-pass filter which reduces high-frequency noise (U14d and U14a). Comparators (or slicers) U16d and U16a detect positive and negative going pulses, respectively. U16b and U16c together output a short digital pulse at the center of either positive or negative pulses. These digital signals are combined in U17, which reconstructs the original data.

As with the transmitter, the signal coming out of the receiver's detector must have the correct waveshape. The audio de-emphasis circuit (usually placed immediately after the detector) will distort the pulse shapes enough to cause unreliable operation. This means that tapping the receive signal from the volume control or speaker won't work.

carrier detect

Our packet radio protocol states that if a channel is busy, one shouldn't begin a transmission. Squelch circuits found in every FM radio duplicate this function. The carrier-detect circuit in this modem works much like the squelch, but rather than muting the audio it generates a logic signal for the TNC.

This is a noise-operated circuit. U15b detects high-frequency audio noise (approximately 11 kHz) where neither audio nor modem pulse energy is present. With no carrier present, there's lots of high-frequency noise to raise the voltage at R74. Smoothing this pulsating waveform is U14b, a low-pass filter. It drives a Schmidt trigger (U3 in the HAPN-1 adapter) logic gate that makes a quick, clean, carrier/no carrier decision.

At these higher bit rates, the switching time from transmit to receive and back becomes more important. In some radios much of this time is wasted by slow squelch action. This one reacts in 10 to 15 milliseconds.

modem switch

A four-pole, two-position electronic switch, U18, is

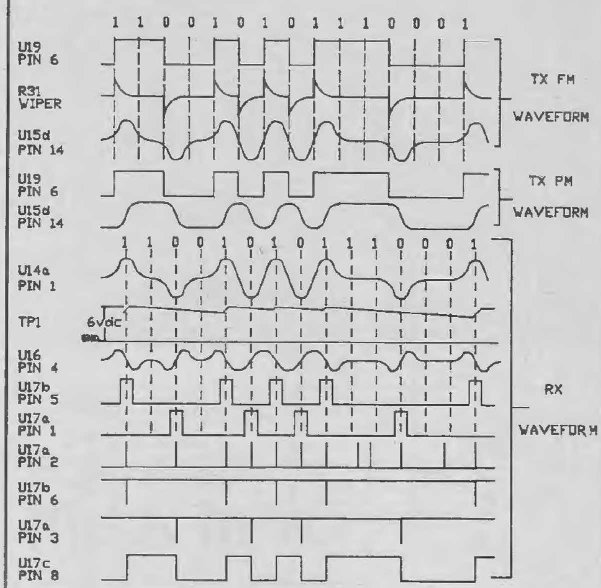

fig. 2. Timing and waveshapes for the 4800 baud modem. Amplitudes are not drawn to scale. There are two possible transmit waveshapes, one for FM and one for PM modulators.

Parts list

Resistors	1/4 watt, 5 percent
R60,R61	= 15
R40	= 100
R71	= 560
R58	= 1k
R78,R79	= 1.8k
R66,R67,R68	= 2.2k
R30,R63,R64,R65	= 3.3k
R73	= 4.7k
R59,R62	= 10k
R39,R53	= 15k
R34,R49	= 39k
R32,R33,R35,R36,R37,R48	= 47k
R46,R47,R50,R51	= 56k
R38,R43,R45,R52,R54,R57,R75	= 100k
R55,R56	= 220k
R77	= 270k
R72	= 330k
R76	= 1 M

Potentiometers = 3386W Type 3/8 square single-turn adjustment
R31 = 5k
R44 = 10k
R74 = 50k

Capacitor voltage rating: at least 16 volts, 10 percent tolerance or better and to have spacing of 0.2".

C31,C32,C33,C34,C38,C39,C40, C47,C50	= 1000 pF
C30,C44	= 4700 pF
C37,C42,C43,C49	= 0.047 μF
C35	= 0.1 μF ceramic bypass
C48	= 0.15 μF
C36	= 4.7 μF tantalum

Diode = Switching /signal-silicon
CR7,CR8,CR9 = 1N914 or 1N4148

Jumpers
J8 = three post jumper
J9 = two post jumper

Sockets = 5 x 14 pin
Sockets = 1 x 16 pin

Integrated circuits
U14 = TL084
U15 = TL084
U16 = LM339
U17 = 74LS00
U18 = 14551
U19 = 74HC00

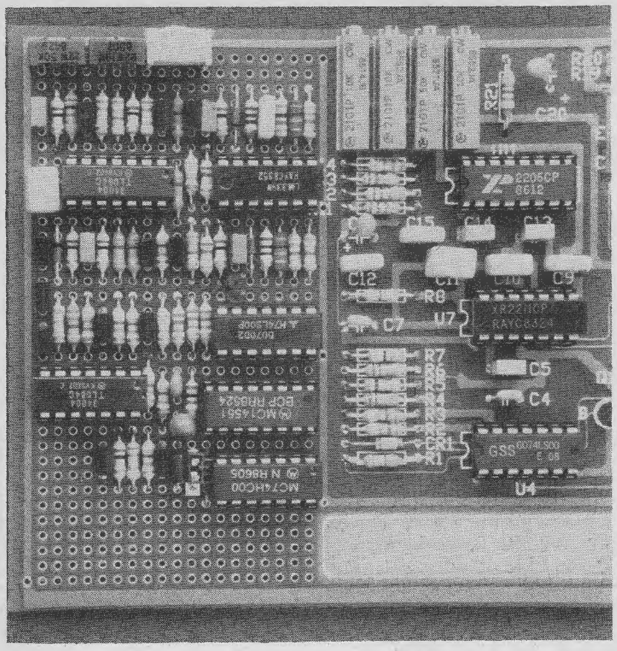

photo A. Close-up of the 4800 baud modem on the HAPN-1 prototype area.

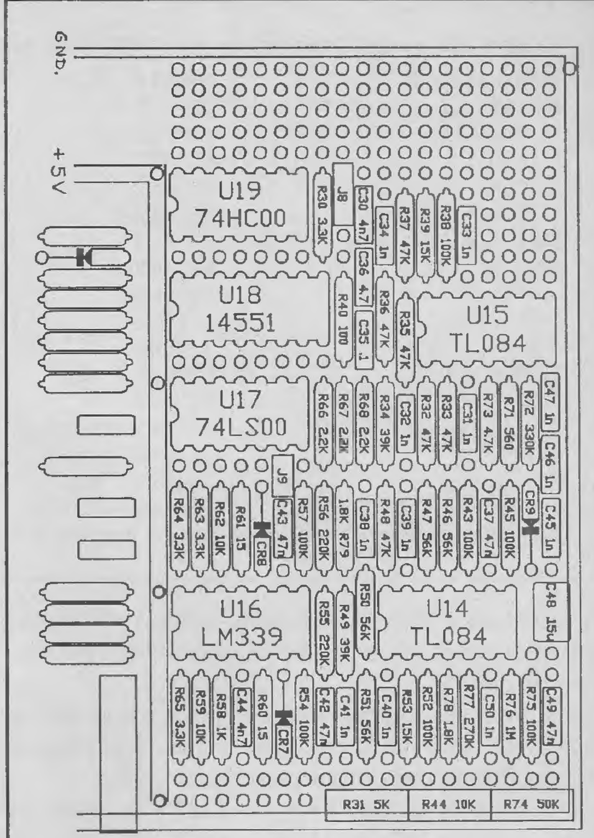

fig. 3. Parts layout diagram from the top of the prototype area.

included to allow software switching from one modem to the other. A logic signal from an unused output line of the 8273 (U6, pin 36) controls the switch.

Since each modem operates at a different bit rate, one of the poles switches the 8273's 32X clock (pin 25) input from the standard 1200 baud position to the 4800 baud position. Another switch position selects the digital data output from one modem or the other. The serial data comes from the switch's pole into the 8273 data input (U4, pin 13).

Because this is a MOSFET switch, it can deal with analog and digital signals. The transmit signal going to the rig's modulator can be routed from one modem or the other by the third switch. Turning the 8273 control port (port B) bits on and off puts the switch under software control. The node customization program supplied with the HAPN-1 adapter provides a modem select menu; choose the modem/baud rate by pressing one of the function keys. The modem/baud rate remains in effect until the customization procedure is used to change the selection again.

construction

The prototype area at the end of the HAPN card is the perfect place to build this modem. (See **photo A.**) Power supply lines (+12 volts, −12 volts, +5 volts, −5 volts) are available, as are all the TNC interface points. Interfacing is shown for the HAPN-1 card; later versions of the card have traces to the interface points brought out to the prototype area, making modem construction a little easier.

You must use small components. The parts layout in **fig. 3** assumes all capacitors have a lead spacing of 0.2 inch. Resistors of 1/4 watt have their leads bent to 0.4 inch.

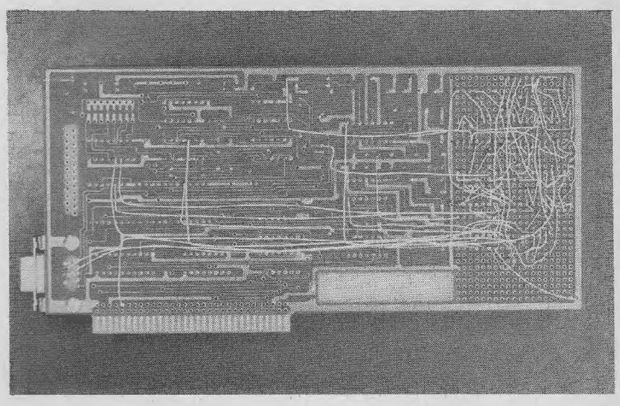

photo B. Bottom of the HAPN-1 adapter showing the wiring added for the 4800 baud modem.

Insert the components according to the layout diagram, and solder them to the board. Then cut the leads off and make the interconnections. A small soldering iron and fine wire (like wire-wrap wire) are a must. Take care with the interconnections; the parts

Table 1. Modem pin designations on HAPN series boards

Signal name	HAPN-1	HAPN-1.1	HAPN-1.2
Rx 4800 audio	DB-9 pin 7	square pad 01	square pad 01
Tx 4800 audio	DB-9 pin 8	square pad 02	square pad 02
−12 volts	C22/R20	square pad 03	square pad 03
32xCLK	U6 pin 25	square pad 04	square pad 04
1200 baud	U8 pin 4	square pad 05	square pad 05
4800 baud	U8 pin 3	square pad 06	square pad 06
Not TxD	U6 pin 29	square pad 07	square pad 07
+RTS	U9 pin 12	U9 pin 12	square pad 08
+12 volts	U11 pin 4	square pad 08	square pad 09
+5 volts	5volt rail	square pad 09	square pad 10
Tx 1200 audio	DB-9 pin 4	square pad 10	square pad 11
1200 RD	U7 pin 7	square pad 11	square pad 12
RD	U4 pin 13	square pad 12	square pad 13
Not PB1	U6 pin 36	square pad 13	square pad 14
CD	U3 pin 9	square pad 14	square pad 15
−5 volts	edge connector B5	square pad 15	square pad 16

Note: Edge connector pin B5 is the fifth pin from the bracket going to the fifth hole on the top row.

are placed very close together and finding a wiring mistake after the modem has been assembled is no fun. (See **photo B.**)

Cut the following two printed circuit traces so the multiplexer chip (U18) can switch from one modem to the other under program control:

1. Cut the default 1200 BPS trace at "SW" (next to P1).
2. Cut the trace going to U4 pin 13. This will be at different locations, depending on the board revision you have:

- HAPN-1 — fat trace on the component side, going to U4 pin 13.
- HAPN-1.1 — short trace between square pad no. 11 and square pad no. 12.
- HAPN-1.2 — short trace between square pad no. 12 and square pad no. 13.

Table 1 shows how the new modem interfaces with different revision boards. The later boards have been enhanced with pads at the prototype area making it easier to add the modem. Square pads are immediately adjacent to the prototype area, in a vertical row. They are consecutively numbered from the top of the board to the bottom.

voltage hookup

Look up the signal name in **table 1** and locate the appropriate interface point for your board.

GND — from any wide ground trace at the side of the prototype area to U17 pin 7, U18 pin 8, and U19 pin 7. Also complete ground side connections to all components needing ground (see schematic, **fig. 1**).

+12 volts — to U16 pin 3, U14 pin 4, and U15 pin 4. Also connect +12 volts to R59.

−12 volts — to U16 pin 12, U14 pin 11, and U15 pin 11. Also connect −12 volts to R62.

+5 volts — to U17 pin 14, U18 pin 16, and U19 pin 14. Also connect +5 volts to R66, R67, R68, and R79.

−5 volts — to U18 pin 7.

Finally, make up a cable for the radio with the following:

- "Rx audio" to DB9 pin 7
- "Tx audio" to DB9 pin 8
- "PTT" to DB9 pin 1
- "GND" to DB9 pin 3

modem/radio interface

One project goal was to maintain the functionality of the existing modem while allowing easy switching between the two. It was also desirable to keep the interface between the modem and the radio as simple as possible.

A quick survey of local hams shows that most would have to change the tap points into their radio for the new modem. *Choose the wrong tap points and this modem will not work!* At this time a wide variety of radios have been adapted successfully with little modification.

transmitter interface

The 4800 modem transmit signal must go directly to the FM or PM modulator in your transceiver. Connections to the microphone jack will not work. Tapping at this point also seems to work well with 1200 baud modems, as long as the level is readjusted to match the new tap point. Because this tap point bypasses the limiter stages in the audio chain, take care not to over-deviate. Deviation should be kept to about 3 kHz by adjusting R31 on the modem. Use shielded cable to connect the modem to your radio.

If you choose the correct tap point, your radio will still operate properly when used for voice work but

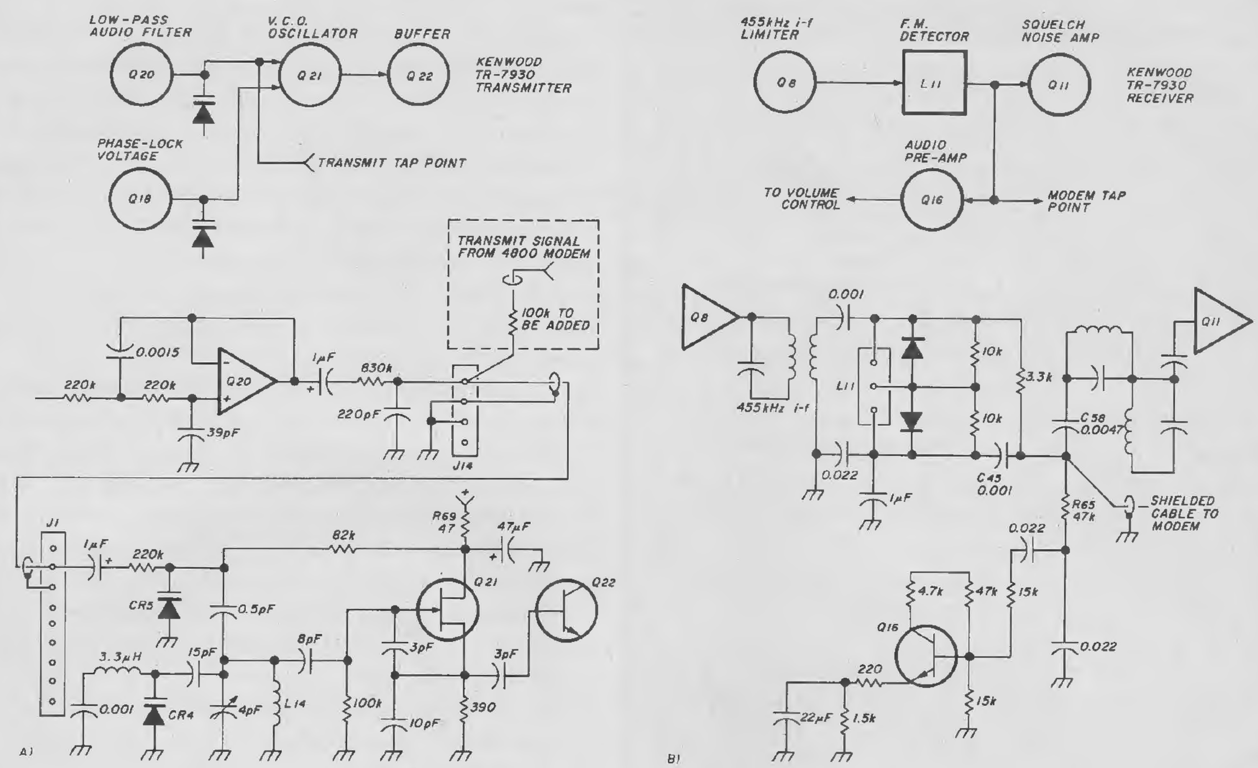

fig. 4. Interface of 4800 baud modem to Kenwood TR-7930 rig. This is typical of many rigs in use today. Find the modulation stage in the transmitter (A), and the FM demodulator in the receiver (B).

you will have to disconnect the modem interface cable to get full voice modulation. When it is used for packet communication, it's a good idea to unplug the microphone to prevent room noise pickup.

You must determine which modulation type your radio uses. If you have a phase modulator, install a jumper between the center pin of J8 and the pin connected to R30. If your rig uses a frequency modulator, install the jumper between the center pin of J8 and C30.

Many radio manuals include a block diagram. This is a useful guide to determine what form of modulation your radio uses. FM is always applied to an oscillator circuit; either a crystal-controlled oscillator or a voltage-controlled oscillator (VCO). If it's FM, your rig's schematic will show a voltage variable capacitance (varactor) diode coupled closely to the frequency determining inductors and capacitors (or crystal) of an oscillator circuit.

Phase modulation is always applied to a stage following an oscillator, never to the oscillator itself. PM could be produced using either a voltage variable capacitance diode or a transistor stage called a "reactance modulator".

The point in your radio where the Tx audio should be introduced must be very close to the modulator. Your rig's audio processing stages will probably end in a low-pass filter before going into the modulator. The tap point will be between the low-pass filter and the modulator itself. If possible, tap in at a high impedance point; the modem shouldn't have to drive an impedance lower than about 400 ohms.

Figure 4A shows an example of the transmitter interface to a Kenwood TR-7930 transceiver.

receiver interface

You cannot use a connection into your rig at the speaker or volume control for this modem. Your rig must be tapped directly at the FM detector before the audio is de-emphasized. The de-emphasis circuit (a resistor/capacitor combination) is rarely identified on schematic or block diagrams. It nearly always follows the squelch pickoff point, but is often placed before any audio gain stages.

Most radios use a squelch circuit called a "noise-operated squelch" that gets its operating signal from the FM detector, before de-emphasis. Tap for the modem at *exactly* the point where this squelch circuit joins the FM detector. The input circuit of the modem is ac coupled, and is high impedance (100k). It can

accommodate signal amplitudes from 2 mv to 200 mv rms.

Some integrated-circuit detector chips include an audio preamp that may supply too much signal for the modem. You can accommodate these larger signals by soldering a resistor (10k to 33k) in parallel with R45.

Use shielded wire between the receiver interface point and the modem. Keep the length as short as possible — avoid a run of more than 10 feet. If you must keep your radio at some distance from your TNC, construct a buffer stage at the detector so that it is not loaded by the capacitance of a long run of shielded cable.

The existing interface for the push-to-talk circuit doesn't need to be changed. Route all signals through the nine-pin connector at the back of the board. You may leave the existing 1200 baud lines on this connector (pins 2 and 4) intact, wiring the new transmit and receive lines to pins 7 and 8. Once you get the new modem running successfully, try switching to 1200 baud using the new tap points in your radio. An adjustment of the 1200 TX level control (P3) should be all that's necessary.

The HAPN card allows two sources of carrier detect — one derived from the demodulator chip (XR2211), the other from an external (squelch-derived) source. A jumper at J1 or J2 selects one of these sources. Jumper J9 selects a third option, the 4800 carrier detect. Because this circuit detects 1200 baud packets, 4800 baud packets, and even voice, remove the jumper on J1 or J2 and install it permanently at J9.

Figure 4B shows an example of the receiver interface to a Kenwood TR-7930 transceiver.

test and alignment

Check the four power supply lines for shorts with an ohmmeter before plugging the modified card back into your computer. After installing the adapter, but before connecting your radio, make sure the dc voltages on all the signal pins of U14 and U15 are 0 volts. Connect your radio and go to a clear channel.

Measure the voltage at TP 1 and adjust potentiometer R44 for about 9 Vdc. This voltage gives the peak amplitude of the audio signal, and should drop to about 6 Vdc during a 4800 baud packet. If R44 adjusts out of range, change R45 up in value if the TP 1 voltage is too low, down in value if it's too high.

Now adjust R74 as you would a squelch control. Use the HAPN "T25" test program to look at the "carrier detect" function. You can also set R74 by looking at U14b pin 7. Adjust for −5 Vdc on a clear channel. It should rise to approximately 0 volts when a carrier is present, or when the radio is disconnected from the modem.

The transmit level control R31 is more difficult to set properly, since you probably have no way of meas-

uring deviation. The 4800 baud deviation should be 3 kHz, a little less than voice deviation of 5 kHz. You might have another station compare the level of your 4800 baud packets with a voice transmission, ideally with a scope. Start R31 off at minimum, increasing it slowly. Setting R31 too high may over-deviate your transmitter and the monitoring station will see only that waveform amplitude is not increasing, although you may be causing adjacent channel interference. Remember that by connecting directly to the modulator you have bypassed the audio limiting circuits; the only thing limiting deviation is R31 in the modem.

The existing factory limiter setting in your radio (which should be close to 5 kHz) can also be used as a reference for setting the 3-kHz deviation for 4800 baud. Hook up your scope at the selected 4800 baud modulating point, apply a signal into the microphone input (use a signal generator or whistle into the mike), and increase the amplitude until you can see limiting on the scope. Note the peak amplitude. This will be your 5-kHz deviation reference. Take 60 percent of this value and use it for adjusting the 4800 baud transmit level (R31). You can also use the same level when adjusting your 1200 baud transmit level (P3).

acknowledgments

This modem is an adaptation of the design by Ken Smith, VE3HWB, so a great deal of credit must go to him. Ken's original article, "Packet Radio with the 1802," was published in the *Ipso Facto* newsletter of the Association of Computer Experimenters (ACE), April 1979. Thanks also to HAPN members VE3IUV, VE3NAV, and VE3MCF for their efforts in building and testing the prototypes, and their contributions to this article.

available from HAPN

The HAPN-1 adapter revision 2 is still available from HAPN as described in the August 1986 article for the same price. Revision 2 contains a number of extra traces in the prototype area to simplify the addition of a second modem there.

We also have a printed circuit board for a stand-alone version of the 4800 baud modem, the HAPN-M, available for $25 U.S. postage paid. The modem is identical to the one described in this article, except that it has RS-232C drivers in the interface to the TNC. It may be used with any RS-232C compatible TNC, or TTL levels if the RS-232C interface circuits are bypassed.

We would like to remind HAPN-1 users who build this modem that a software update may be required to fully support the modem switch. Software updates are $5 U.S. each, plus $5 per diskette. (If you use any of the programs on diskette 2, a diskette 2 update is required along with diskette 1.)

Wiring diagrams of the modem and interfacing diagrams for the Santec ST-144/uP handheld and the ICOM IC-27 transceivers are available from HAPN if you send us a self-addressed envelope and an IRC.

HAPN update

HAPN (Hamilton and Area Packet Network) is a nonprofit association dedicated to furthering the state of packet radio. We are presently working on the TAPR-2 TNC version of the 4800 baud modem and on developing drivers for the VADCG V-3 experimental protocol. We believe that widespread use of 4800 baud will go a long way to improve the efficiency of packet radio local area networks, at minimal cost to the users. The V-3 link level driver is being tested, but the network level is yet to be coded. V-3 is a very interesting networking protocol, an outgrowth of VADCG's V-2 protocol. (For further information on V-3 write VADCG, 9531 Odlin Road, Richmond, BC, V6X 1E1, Canada.)

reference

1. Jack Botner, VE3LNY; Ron Bradshaw, VE3IUV; Max Pizzolato, VE3DNM; John Vanden Berg, VE3DVV; "A Packet Radio TNC for the IBM PC," *ham radio*, August 1986, page 10.

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